TITLE

# LIFTING DEVICE FOR FULLY PLANING OR SEMI-PLANING WATERCRAFTS

## DESCRIPTION

### Field of the invention

The present invention generally relates to the nautical field and more precisely it relates to a device applicable to a watercraft, in particular a fully planing or semi-planing watercraft, to increase the hydrodynamic lift on the bottom thereof.

### Description of the prior art

As known, fully planing or semi-planing watercrafts during navigation find a floating contribution from the dynamic reaction of water on the bottom.

In figure 1 the dynamic equilibrium that balances the navigation of a watercraft of this kind is diagrammatically shown: the weight (1) in fully planing or semi-planing watercrafts is not balanced by the sole hydrostatic lift but by the involvement of two forces, one of which is a fraction of the hydrostatic lift (2) that would balance the motionless floating boat, and the other is the hydrodynamic lift (3) as generated by the dynamic action of the water on the bottom of the watercraft. The equilibrium between the combination of these two forces and the weight force (1) is dynamical, since:

- the point of application of the hydrodynamic lift (3) changes as varies the wetted surface of the bottom, whereas its absolute value depends on the speed (4);
- the fraction of hydrostatic lift (2), corresponding to the water displaced by the wetted part of the bottom, changes in intensity and point of application as the dipping of the aft bottom varies, in a way responsive to the moment of the hydrodynamic lift (3)

with respect to the barycentre (5) for achieving a balanced position.

When the watercraft navigates in a fully planing way the waterline 8 is inclined at an angle $\alpha$ with respect to the waterline 9 of the watercraft that navigates in a displacing way, owing to the water mass that is continually displaced for hydrostatic lift, which is a passive work that causes a great power absorption.

Therefore, it is desirable that the hydrodynamic lift (3) bears the maximum part of weight of the watercraft and the hydrostatic lift (2) is used only to assure the equilibrium.

This theoretical optimal condition can be rarely achieved, because the hydrodynamic lift on the bottom almost always has such an high value that it can supporting the maximum part of the weight of the watercraft. The hydrostatic lift, then, not only fulfils the above equilibrium condition, but bears also a much higher fraction of weight of the watercraft that should have been born by the hydrodynamic lift in a good watercraft design. This occurs because the manufacturing techniques of watercrafts leads normally to a weight much higher than an optimal as regards to the maximum hydrodynamic lift on the bottom, except from experimental or racing watercrafts that however require very expensive construction techniques. Furthermore, even if the weight of the watercraft is optimal, often the load of the watercraft is so high that the optimal ratio between weight and hydrodynamic lift cannot be reached.

For improving the performances of fully planing watercrafts and for resolving possible construction defects two types of devices are known: the "flaps" and the "trimming surfaces". Both are used at the aft bottom and cause a push towards the above deviating towards below the water that flows along the bottom.

In particular, the flaps are horizontal sheets, adjustable in height in order to change their incidence, and deflect the flow that has left the aft bottom. The trimming surfaces, instead, are fixed and deflect the flow under the aft bottom part. The forces thus generated have a moment with respect to the barycentre that changes the longitudinal trim. They are used when, for defective design or for high load, the barycentre is shifted towards the aft bottom from its ideal point, in order to correct the longitudinal trim.

These devices, therefore, are used essentially to adjust the trim of the watercraft, and are of no use to increase the hydrodynamic lift.

Summary of the invention

It is therefore a feature of the present invention to provide a lifting device for watercrafts, in particular of the fully planing or semi-planing type, which allows to improve its performances versus higher speed under a same fuel consumption and power absorption, or versus less fuel consumption and power absorption at a same speed, without changing the dynamic equilibrium.

It is another feature of the present invention to provide such a device that improves the comfort of the watercraft in navigation with rough sea.

It is a further feature of the invention to provide a device that reduces to a minimum the resistance in water of the watercraft both in planing navigation an in displacing navigation and without affecting the steering effectiveness.

This and other objects are accomplished by the lifting device for watercrafts, in particular of the type with fully planing or semi-planing bottom, whose main feature is to provide at least a transversal element constrained to the watercraft at a predetermined distance from the bottom and suitable to increase the hydrodynamic lift on the bottom.

Advantageously, the or each transversal element is arranged selected from the group of: substantially parallel to the bottom of the watercraft, or inclined with respect to the bottom of the watercraft.

Preferably, means are provided for adjusting the inclination of the or of each transversal element with respect to the surface of the bottom and, therefore, with respect to the water flow. The means for adjusting the inclination of the or of each transversal element are selected from the group of mechanical, manual, hydraulic, pneumatic or electromechanical means. More in detail, the adjustment can be obtained both changing the incidence of the entire planar surface, both changing the incidence of the sole rear part with respect to the water flow.

In particular, the transversal element in use has an upper surface that faces the bottom of the watercraft and a lower surface opposite to the upper surface, said transversal element being subject to a lifting force perpendicular to the lower surface owing to the difference of pressure between the two surfaces when navigating. Therefore, the transversal element is a lifting element capable of increasing the hydrodynamic lift that balances the weight of the watercraft during navigation.

Advantageously, the transversal element is arranged below the bottom at the barycentre of the watercraft. Or, the transversal element is arranged shifted with respect to the barycentre for correcting the trim of the watercraft.

Preferably, the or each transversal element is bridged to the surface of the bottom. In particular, the or each transversal element is constrained below the bottom of the watercraft by at least two support elements substantially orthogonal to the waterline. Preferably, a support element is provided at each end of the transversal element.

In particular, the or each support element is a shaped plate with an opening, for not affecting the trim when steering the watercraft, said plate being arranged substantially orthogonal to the waterline.

In a possible exemplary embodiment the transversal element is made of a substantially V-shaped single part arranged transversally to the bottom of the watercraft. In particular, this single part crosses transversally the bottom of the watercraft for substantially all its width and more. In this case, support elements can be provided also near the vertex of the "V" to provide a steadier fastening to the bottom.

In another exemplary embodiment of the invention a lifting device comprises at least a first and a second transversal element of the type above described fixed in different points of the bottom symmetrically to its longitudinal midplane.

A further exemplary embodiment of the device provides at least a first and a second transversal element as above described arranged with the respective surfaces on planes substantially parallel to each other. This way, an effect of additional hydrodynamic lift is obtained on two parallel surfaces.

Advantageously, the or each transversal element as above described is located at a distance from the bottom to work always dipped in the mass water. This way, the positive effect of the transversal element on the overall hydrodynamic lift on the watercraft is optimised and also the condition of equilibrium for navigating is not affected. More in detail, the minimum distance of the or of each transversal element from the bottom must not affect the water flowing thereon.

According to another aspect of the invention a bottom for watercrafts in particular of the fully planing

or semi-planing type, has the feature of having at least one lifting device as above described.

Brief description of the drawings

The invention will now shown with the following description of an exemplary embodiment thereof, exemplifying but not limitative, with reference to the attached drawings wherein:

- figure 1 shows diagrammatically the dynamic equilibrium during navigation of a fully planing or semi-planing of prior art watercraft as above described;
- figure 2 shows diagrammatically the dynamic equilibrium during navigation of a watercraft on which a device to increase the hydrodynamic lift acting on the bottom of the watercraft in planing navigation, according to the invention, is installed;
- figure 3 shows a perspective view of a possible exemplary embodiment for a device to increase the hydrodynamic lift on the bottom of the watercraft in planing navigation;
- figures 4 and 5 show the device of figure 3 respectively in a perspective elevational front view and an oblique perspective view installed on a planing watercraft;
- figures 6 and 7 show an alternative exemplary embodiment of the device of figure 3 installed on a planing watercraft in a perspective elevational front view and an oblique perspective view respectively;
- figure 8 shows a perspective view of a further alternative exemplary embodiment of the device of figure 3 "castle-like" provided by the present invention;
- figure 9 shows a perspective view of the possibility of equipping the device of figure 3 or 6 with means for changing its inclination with respect to the surface of the bottom and then the incidence with respect to the flow in which it is dipped;

- figure 10 shows diagrammatically the correction of the dynamic equilibrium when using the device of figure 3 on a watercraft with a forwardly shifted barycentre;
- figure 11 shows diagrammatically how the dynamic equilibrium changes ,on watercrafts that have the barycentre too close to the point of application of the hydrodynamic lift, using the device of figure 3.

Description of the preferred exemplary embodiment

With reference to figure 2, a lifting device 10 for watercrafts of the fully planing or semiplaning type provides at least a transversal element 15 constrained to bottom 25 by means of supports orthogonal to the waterline 8 and suitable to increase the hydrodynamic lift acting on the bottom 25.

The position indicated in figure 2 of the device 10 is under barycentre 5, and generates, when in navigation at a sufficient speed 4, an additional hydrodynamic lift 6, indicated as resultant applied to barycentre 5, which adds to hydrodynamic lift 3 on the bottom and to the hydrostatic lift 2 for balancing the weight of the watercraft.

The transversal element 15 is arranged substantially parallel to the watercraft bottom 25, so that in fully planing or semi-planing conditions it is inclined with respect to the speed 4 of the watercraft.

Therefore, the addition of the lifting surface 15, adding the surplus of hydrodynamic lift 6, serves to support much more weight decreasing the dipped part of the watercraft that provides the hydrostatic lift 2. This way it is possible to reduce the amount of water displaced thus approaching the minimum value necessary to obtain an optimal planing.

The position of transversal surface 15 is very effective with respect to the planing part of bottom 25 because it is always dipped in the water flow, without

exiting from the water surface when the watercraft is pitching or "pumping", thus supplying a substantially steady hydrodynamic lift, directly proportional to its surface and to the square speed value.

From a physical viewpoint, using the formula of the hydrodynamic lift

$$P = \tfrac{1}{2}\, C_p \cdot \rho \cdot S \cdot V^2$$

where

Cp = Hydrodynamic lift coefficient

$\rho$ = Density of mass of the water (104,5 $Kg^2$ x sec./m)

S = Lifting surface ($m^2$)

V = Speed (m/sec)

It is clear that not too large surfaces can generate significant lifting forces even with low values of the hydrodynamic lift coefficient.

For example, a hydrodynamic lift coefficient of 0,25 is easily obtainable with a surface without any design of its profile aimed at increasing its profile hydrodynamic efficiency. In such a case, for a plane surface of 0,18 $m^2$, with an angle of incidence of 3-4 degrees and a speed of 18 m/sec, a hydrodynamic force P is obtained of about 700 Kg that has to be broken down into the two components vertical 6 ($P \cdot \cos\alpha$) and horizontal $P \cdot \mathrm{sen}\alpha$, with $\alpha$ angle of incidence. The braking component $P \cdot \mathrm{sen}\alpha$ is normally less than one tenth of the lifting component.

Surface 15, notwithstanding indicated as plane and with generically rectangular cross section, will have actually a suitably shaped wing-like profile of known design. A suitably studied hydrodynamic surface can have a much higher hydrodynamic lift coefficient (even 1-1,2).

In view of the above, lifting surface 15 of figure 2, according to the invention, gives an additional contribution to the lift of the watercraft, decreasing the displaced mass of water during navigation of the watercraft and decreasing

the power absorption at a same speed, without changing the typical position of equilibrium. In fact, as shown in figure 2, the part of weight 1 balanced by the additional hydrodynamic lift 6, under a same hydrodynamic lift 3 generated by the bottom, requires a much lower hydrostatic lift 2. The lower value of hydrostatic lift 2 requires that less water be moved during navigation.

It can be noted from figure 2, furthermore, that by arranging device 10 under barycentre 5 the distribution of forces has not changed, because only their intensity and the point of application of their resultant has changed. In particular, the moments of hydrodynamic lift 3 and of the hydrostatic lift 2 with respect to barycentre 5 balance each other in a way similar to figure 1, since the additional hydrodynamic lift 6, which is centred on barycentre 5 does not add any contribution to the moments.

The equilibrium of figure 2 causes a lower overall resistance, consequently increasing the speed. The limit balance conditions occur when the hydrodynamic lift, consisting of the sum of the contribution 3 due to bottom 25 and of the contribution 6 due to surface 15, is less than the value of the weight force 1 of an amount that corresponds to a minimum water mass 2 capable of generating the hydrostatic lift to reach the equilibrium.

According to the invention it is therefore possible to improve the operative conditions of fully planing or semi-planing watercrafts without that the bottom looses contact with the water at speeds that are normally less than those of hydrofoil boats. A skilled person for maximising effectiveness, depending on the design features of the watercraft, chooses the size of surface 15 easily.

Device 10, in addition to increasing the hydrodynamic lift on watercraft 25, allows also improving the comfort of the watercraft in navigation with rough sea. In fact, in the

presence of waves the bottom 25 transmits to the watercraft noisy and violent hits. In particular, with rough sea, when passing a wave the front part of bottom 25 of the watercraft falls downwards in the gap between two waves splashing on the water owing to speed and weight. In this case, the presence of lifting surfaces 15 under the bottom would reduce the hit on the water causing it to be more gradual. In fact, if the gap between two waves is not very deep the lifting surfaces would remain dipped, and the splashing fall is braked by their hydrodynamic lift; if instead the gap between two waves is very deep and the lifting surfaces are momentarily undipped, since they are arranged under the bottom at a certain distance, they would contact the water before the bottom and in this fraction of time an hydrodynamic lift is created that would cause the splash to be less violent. For example, the device 10 can be located at a distance from bottom 25 of about 20-40 cm, in such a way to work always dipped in water. This allows to optimize the positive effect of transversal element 10 on the overall hydrodynamic lift acting on the watercraft and not to affect the balance of the watercraft during navigation.

It must be noted that lifting surface 15 not only gives minimum additional resistance in water of the watercraft in planing navigation, with respect to the lifting force generated, but also in case of displacing navigation the additional resistance is minimum and steering of the watercraft is not affected.

Another advantage of the device above described is the possibility of correcting some trimming defects of the fully planing watercrafts for which the prior art has not a specific remedy:

- In particular, watercrafts that have an advanced position of barycentre 5 have a much low planing efficiency. In fact, the resultant of planing forces would

pass through the barycentre or very close to it, practically not allowing a planing navigation. Instead, after arranging a lifting device 10 shifted forwardly with respect to barycentre 5 (figure 3), at an appropriate distance from it with respect to a vertical line, the total hydrodynamic lift 3′, obtained from the sum of hydrodynamic lift 6 and of additional hydrodynamic lift 6 of figure 2, would shift to a desired point 13 to obtain an dynamic equilibrium correct.

– Furthermore, watercrafts that have a position of barycentre 5 too close to the point of application of the hydrodynamic lift cause a so-called "pumping" navigation. These watercrafts, in fact, in their movement oscillate periodically in a direction aft - prow. This is caused by hydrodynamic lift 3 of figure 1 shifted towards aft behind barycentre 5 at each small oscillation caused by the liquid surface. Once it is shifted behind barycentre 5 the condition of equilibrium is not any more met and the boat would lower the prow shifting forward the hydrodynamic lift 3 before barycentre 5. The equilibrium is restored, but is lost again immediately causing an unavoidable oscillation. Instead, after arranging a lifting device 10, as shown in figure 3, at an appropriate distance before barycentre 5 the centre of application of the hydrodynamic lift 3′ is shifted to a correct position for a steady navigation.

In addition, the device according to the present invention can be mounted on existing watercrafts in a very simple way, improving the performances both if centred under the barycentre and if shifted to correct defects. In both cases, in fact, device 10 is completely external to the bottom and can be fixed to all watercrafts, with easy operations for fixing the lifting surfaces in suitably strengthened points.

As shown in figures 4, 5 and 6, in different perspective views, in a first exemplary embodiment the transversal element 15 is bridged to bottom 25 by means of support elements 11, flanged and connected substantially orthogonal to the bottom same. In particular, support elements 11 are plates having an opening 12, for not affecting the trim when steering the watercraft. In figures 4-6 transversal element 15 is made of a substantially V-shaped flat element arranged transversally to watercraft bottom 25. This way, this single part transversal element 15 crosses transversally watercraft bottom 25 for substantially all its width, and support elements 11 are provided also near the vertex of the "V" to provide a steadier connection to the bottom near the keel. Surface 15 can also having a width larger than bottom 25, in case a great additional hydrodynamic lift is required by the design of the watercraft.

Alternatively, as shown in figures 7 and 8 in two different perspective views, two surfaces 15 are provided at opposite sides with respect to the keel, each with support elements 11 at the ends.

In a further exemplary embodiment, as shown in figure 9, to increase further the hydrodynamic lift on bottom 25, a first and a second surface 15 and 15′ are provided, arranged in planes substantially parallel to each other. This way, a doubled additional hydrodynamic lift is obtained on two parallel surfaces.

Finally, as shown in figure 10, it is possible to adjust the inclination of transversal element 15 with respect to bottom 25 and, therefore, with respect to the water flow. In figure 10 the adjustment is obtained changing the incidence of the sole rear part with respect to the water flow. However, also the incidence of the entire planar

surface 15 can be changed. This way, the additional hydrodynamic lift can be optimized according to a desired angle of inclination of the bottom with respect to the waterline, as the speed of the watercraft changes. The means for operating the inclination can be actuators, of known type to a skilled person, which transmit a movement by a stem not shown arranged along a support element 11.

The foregoing description of a specific embodiment will so fully reveal the invention according to the conceptual point of view, so that others, by applying current knowledge, will be able to modify and/or adapt for various applications such an embodiment without further research and without parting from the invention, and it is therefore to be understood that such adaptations and modifications will have to be considered as equivalent to the specific embodiment. The means and the materials to realise the different functions described herein could have a different nature without, for this reason, departing from the field of the invention. It is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.